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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,430,088**, on May 23, 2003, by **ACS ENGINEERING TECHNOLOGIES INC.**, assignee of Sujit K. Sarkar, for "Steam Generation Apparatus and Method".

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Abstract of the Invention

In one aspect, the invention provides a steam generation apparatus that is liquid fuel fired and addresses conversion of gaseous fuel SIB units to operate with liquid fuel. The invention also relates to a conversion unit for a steam injection boiler, a method for converting a steam injection boiler from gas firing to possible liquid fuel firing and a method for generating steam from a liquid fuel source. The invention employs a fired heater for heating the liquid fuel to a temperature suitable for firing and preheats the water to compensate for the shortfall in heat liberation when a gas boiler is converted to use liquid fuel. In another aspect of the invention, production of greater than 80% quality steam is achievable consistently by employing step-up heaters with a steam injection boiler. The heaters being connected in parallel to continue heating the water/steam to achieve a higher quality steam without consideration as to the effects of coil fouling.

STEAM GENERATION APPARATUS AND METHOD

Field of the Invention

The present invention relates to steam generation apparatus and, in particular, steam generation apparatus for secondary recovery of oil, a conversion unit for steam generation apparatus and methods for steam generation and conversion of steam generation apparatus.

Background of the Invention

In the petroleum industry, steam can be used for the recovery of bitumen or heavy oil from oil-bearing formations. A common process utilized for the in situ recovery of heavy oil or bitumen is to inject steam underground pursuant to which the viscosity of bitumen or heavy oil is decreased such that it flows and is capable of being pumped to the surface. For this, steam generation equipment commonly called steam injection boilers ("SIB") are used to generate steam of the required / desired quality.

For in situ recovery of bitumen or heavy oil, prominent processes utilized are steam assisted gravity drainage ("SAGD") and cyclic steam stimulation, with the SAGD process gaining in popularity due to it capabilities for enhanced recovery of bitumen or heavy oil. Generally, 80% quality steam (i.e. 80% steam and 20% water) is generated by the boiler in specified volumes per hour depending on output capabilities of the boiler, as well as steam output requirements for the recovery and extraction process. Exceeding 80% quality steam typically results in escalating cost due to water treatment costs, potentially rendering a project uneconomical. Conversely, lower than 80% quality steam introduces inefficiencies to the process utilized for heavy oil or bitumen recovery and, hence, is also undesirable from a cost perspective.

Current SIB unit designs generally include horizontal cylindrical units including a combustion chamber with a burner at one end and steam generating coils therein, such as helical or serpentine steam generating coils, etc.. Since almost all SIB units are fired with gaseous fuel (i.e. natural gas or liquid petroleum gas), these units are designed to suit the firing of this gaseous fuel.

Unfortunately, however, the gaseous fuel must often be piped significant distances to the location of steam generation, resulting in a significant cost to the producer due to the price of the gaseous fuel and the cost of the associated pipeline construction and maintenance. In fact, it has been stated that the economics associated with the in situ recovery of bitumen or heavy oil are primarily driven by the price of the gaseous fuel required to generate steam.

Thus, there is a desire in the industry to move to lower cost and/or more accessible fuels. The logical choice would be to fuel the steam generator using a small portion of the heavy oil or bitumen being produced at the site. However, conversion of SIB units from gas fuel to liquid fuel, such as heavy oil or bitumen, has been problematic for a number of reasons.

For example, since the flame resulting from firing natural gas is generally shorter than the flame resulting from firing liquid fuel, such as bitumen or heavy oil, the conversion of an existing SIB unit from gas firing to liquid fuel firing inevitably leads to lower firing rates as the combustion chamber of an existing SIB unit is only designed and sized to accommodate operating conditions incidental to gas firing. While lower firing rates of bitumen can be used and adjusted to mimic the gaseous fuel flame envelope size restrictions of the existing combustion chamber, these lower firing rates result in lower steam generating capacity, as well as lower quality steam (i.e. less than 80% quality). Combusting bitumen or heavy oil also requires the utilization of emission reduction / abatement technologies and equipment, as these liquids generally contain sulfur and other metallic components, resulting in undesirable by-products when combusted.

Even in new installations, the problems associated with liquid fuel firing has driven the industry to continue to use gaseous fuels. For example, a much larger combustion chamber is required for an oil-fired boiler to produce steam of the required quality and in the required amounts. This results in extra costs for equipment, transport and installation.

Summary of the Invention

The invention provides a steam generation apparatus that is liquid fuel fired and addresses conversion of gaseous fuel SIB units to operate with liquid fuel. The invention also relates to a conversion unit for a steam injection boiler, a method for converting a steam injection boiler from gas firing to possible liquid fuel firing and a method for generating steam from a liquid fuel source. In one aspect of the invention, production of greater than 80% quality steam is achievable consistently without the incurrence of certain water pre-treatment costs.

In accordance with a broad aspect of the present invention, there is provided a steam generation apparatus comprising: a fired steam injection boiler including a burner open thereto; a fired heater including a heater burner open thereto; a water tube circuit extending through the heater combustion chamber and through the steam injection boiler combustion chamber, the water tube circuit selected to convey water in order to heat the water to generate steam; a fuel tube extending through the heater combustion chamber selected to convey liquid fuel in order to heat the liquid fuel to a temperature suitable for firing and thereafter conveying the heated liquid fuel to support the firing of the steam injection boiler and the fired heater.

In accordance with another broad aspect of the present invention, there is provided a steam injection boiler conversion unit for converting a steam injection boiler from gaseous fuel firing to be capable of liquid fuel firing, the steam injection boiler including a burner operable therein and a boiler tube circuit extending therethrough, the steam injection boiler conversion unit comprising: a fired heater including a heater burner; a fired heater tube extending through the heater combustion chamber, the fired heater tube circuit selected to convey water in order to heat the water and the fired heater tube circuit being connectable into fluid flow communication with the boiler tube circuit such that, when connected, water passes through both the fired heater tube and the boiler tube circuit for the generation of steam; a fuel tube extending through the heater combustion chamber, the fuel tube selected to convey liquid fuel in order to generate heated liquid fuel; and a conduit connectable into fluid flow communication with the burner of the boiler for supplying the heated liquid fuel to support the firing of the boiler burner, when the conduit is connected to the boiler burner.

The fired heater serves two main purposes: (i) it heats the liquid fuel to the temperature required for firing; and (ii) it increases the heat of the water/steam beyond that heat generated in the boiler such that the heat available from liquid fuel firing in the steam injection boiler is adequate to meet both steam throughput and steam quality, for example to 80% quality, requirements upon outlet from the steam generation apparatus. The combustion in the fired heater can be controlled to control steam quality and throughput. This control can be achieved by adjustment of the firing rate of the fired heater.

The liquid fuel can include, for example, bitumen or heavy oil. Of course other fuels such as medium oil, light oil, etc. could be used but, these fuels may not, when compared to the lower grade fuels, be as economical or as readily available on site at the in situ operations where steam generation is required and, therefore, may result in some or all of the disadvantages experienced when using gaseous fuel fired steam generation.

To handle liquid fuel, the boiler gas burner is replaced with a burner capable of handling liquid fuel, for example, including an atomizer and an inlet for an atomizing steam supply. In one embodiment, for smaller boilers, a dual fuel burner can be used that is capable of using both gaseous and liquid fuels. In many larger sized boilers, for example those capable of generating more than 50,000 pounds of steam per hour, dedicated liquid fuel burners need to be used. Thus, if it is later desired that the boiler be returned to gaseous fuel burning, the boiler oil burner would need to be replaced with a gas burner. However, as advances in burner technology occur, dual fuel burners in larger sized boilers may become feasible.

The fired heater can be fired by any desired fuel. However, it is advantageous for the fired heater to also be fired by liquid fuel. Thus, in one embodiment, a conduit can be provided for conveying the heated liquid fuel to support the firing of the heater burner and the heater burner is adapted for burning liquid fuel and, for example, includes an atomizer and an inlet for a steam supply. In such an embodiment, a connection to an alternate fuel supply may be provided to permit operation of the fired heater by means of that alternate fuel source, such as a gaseous fuel including for example propane, liquid petroleum gas or natural gas. This is particularly useful during initial start up of the steam generation apparatus or the converted steam injection boiler,

since there may be no liquid fuel yet produced or the liquid fuel may not be in a heated condition ready for use as a fuel in either the boiler burner or the heater burner.

The fired steam injection boiler and the fired heater will each have exhausts from their combustion chambers for outlet of combustion gases. Combustion of some liquid fuels can generate unfavorable by-products, and it is desirable to maintain the net undesirable emissions arising from the combustion of liquid fuel to a level not greater than the emissions arising from the combustion of natural gas. Thus, in one embodiment, the exhausts are each provided with a scrubbing device to reduce emissions of unfavorable by-products such as nitrogen oxides (NOx) and sulfur oxides (SOx). In another embodiment, an exhaust arrangement can be provided that includes a scrubbing device but includes a means for controlling the outlet of combustion gases such combustion gases are passed through the scrubbing device. This can be achieved, for example, by use of a damper-controlled bypass. In yet another embodiment, the exhaust of the fired steam injection boiler and the exhaust of the fired heater are connected to share a scrubbing device.

In accordance with another broad aspect of the present invention, there is provided a method for converting a steam injection boiler from gaseous fuel firing to be capable of liquid fuel firing, the steam injection boiler including a combustion chamber with a burner open thereto and a boiler tube extending therethrough, the method for converting comprising: providing a fired heater including a heater combustion chamber, a heater burner, a fired heater tube extending through the heater combustion chamber, the fired heater tube selected to convey water in order to heat the water and a fuel tube extending through the heater combustion chamber, the fuel tube selected to convey liquid fuel in order to generate heated liquid fuel; bringing the fired heater tube in fluid flow communication with the boiler tube such that fluid passing from the fired heater tube can pass into the boiler tube; and conveying the heated liquid fuel to the burner of the boiler to support the firing of the steam injection boiler.

In one embodiment, the exhaust systems for outlet of combustion gases from the steam injection boiler is modified to address emissions. For example, the method may include fitting the exhaust system with a scrubber device.

The invention permits a gas fired steam injection boiler to be converted and retrofitted with minimal interference to its operation. Most of the modifications may be carried out while the steam injection boiler continues in operation with little downtime required to finalize the conversion.

In accordance with another broad aspect of the present invention, there is provided a method for generating steam for in situ production of petroleum products, the method comprising: providing a steam generation apparatus including a fired steam injection boiler including a combustion chamber with a burner open thereto; a fired heater including a heater combustion chamber and a heater burner; a water tube extending through the heater combustion chamber and thereafter through the steam injection boiler combustion chamber, the water tube selected to convey water in order to heat the water to generate steam; a fuel tube extending through the heater combustion chamber selected to convey liquid fuel in order to generate heated liquid fuel; and a conduit for conveying the heated liquid fuel to support the firing of the steam injection boiler; firing the fired heater to heat a supply of liquid fuel passing through the fuel tube; conveying the liquid fuel through the conduit to support firing of the steam injection boiler; passing a flow of water through the water tube such that steam is generated.

The liquid fuel can be taken from in situ production. It may be advantageous to use the liquid fuel while it retains latent heat from production so that it has a viscosity that facilitates handling.

Brief Description of the Drawings

A further, detailed, description of the invention, briefly described above, will follow by reference to the following drawings of specific embodiments of the invention. These drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. In the drawings:

Figure 1 is a schematic drawing of a prior art steam injection boiler.

Figure 2 is a schematic drawing of a conversion unit according to the present invention for conversion of a steam injection boiler from gas-firing to liquid fuel firing capability.

Figure 3 is a schematic drawing of a steam generation apparatus according to the present invention.

Figure 4 is a schematic drawing of another steam generation apparatus according to the present invention.

Figure 5 is a schematic drawing of another steam generation apparatus according to the present invention.

Figure 6 is a schematic drawing of another steam generation apparatus according to the present invention.

Detailed Description of the Invention

Referring to Figure 1, a prior art steam injection boiler B1 is shown. Similar steam injection boilers are alternately termed "steam flood boilers", "water flood boilers" or "once through steam generators". Some of the leading manufacturers include Struthers Industries Inc., Gulfport, Mississippi, HTH Heatech Inc., Calgary, Alberta and Applied Thermal Systems (ATS) Inc., Tulsa, Oklahoma.

The steam injection boiler includes a combustion chamber defined by an outer wall 6. Combustion chamber includes a burner 16 for handling gaseous fuel such as liquid petroleum gas or natural gas supplied through line 40. Burner 16, when in operation, creates, a flame shown in phantom as 37, and combustion chamber thereby includes a radiant zone, a convection zone 31 and an exhaust stack 28. The outer wall has a refractory lining 18.

A feed water line 19 feeds water by use of a feed pump 33 to coils in the boiler for the generation of steam from the water. In particular, feed water line 19 leads first to a preheat coil 21 disposed in the convection zone. Preheat coil then feeds through a line 19a to inlet 35 and steam coils 5 in the radiant zone. Coils 21 and 5 are supported within the boiler on supports 17 such that they are disposed, for example, in a helical or serpentine arrangement.

A line 38 leads from steam outlet 20 to feed steam generated in boiler B1 to the well.

When in operation, burner 16 is fired by gaseous fuel through line 40 to generate flame 37 within the combustion chamber. Combustion gases exit the chamber by passing through convection zone 31 and exhaust stack 28. Water, which is under pressure and may be treated to adjust its mineral content, is fed through line 19 to preheat coils wherein the water temperature is increased by heat exchange with the combustion gases. The preheated water is then conveyed via line 19a to coils 5 in the radiant zone of the boiler. The water in the tubes is driven to its steam state while passing through the radiant zone such that when in exits at outlet 20, it is in a state ready for passing to the well to drive in situ production. Selection steam quality at outlet 20 is achieved through selection of flame 37 heat release.

Boilers such as boiler B1 are sized and configured to accommodate a flame generated by a gaseous fuel. The flames generated from gaseous fuel combustion generally have a smaller envelope/BTU (British thermal unit) than the envelope/BTU of a flame generated by use of a liquid fuel, such as bitumen or heavy oil. Straight conversion of a steam injection boiler from gaseous fuel firing to liquid fuel firing with a similar BTU flame is not possible since the combustion chamber is not sized to accommodate the liquid fuel flame. In particular, the liquid fuel flame would impinge on coils 5 or end 42 and cause them to burn out. If the boiler is fired with liquid fuel, therefore, lower BTU's must be used, resulting in a reduction in heat release and, in turn, lower quality steam generation which is generally not desirable for in situ production.

Thus, referring to Figure 2, a conversion unit 44 has been invented for fitting to a steam injection boiler such as boiler B1 of Figure 1, so that the boiler can be used with liquid fuel. While a particular boiler configuration has been illustrated, it is to be understood that other steam injection boiler configurations are known and can be converted in accordance with the present invention.

Conversion unit 44 includes a fired heater H1 including a combustion chamber defined by an outer wall 46. Combustion chamber includes a burner 24, which can be selected for gas-firing or, as in the illustrated embodiment, is capable of firing either gaseous or liquid fuels, or both. Such burners are available from Coen Company, Inc., Burlingame, California or Hamworthy Combustion Engineering, Poole, the UK. To accommodate firing, liquid fuel requires heating and atomization for effective burning. Therefore, a line 12 supplies burner with heated liquid fuel, which is atomized with steam from line 3a. The heated liquid fuel is supplied from a fuel handling system 10 and steam is fed from steam generation, as will be described in greater detail hereinbelow. Line 12 can also be used to supply gaseous fuel to the burner. In another embodiment, a dedicated line 12a for gaseous fuel supply can be provided.

Burner 24, when in operation, creates, a flame such that combustion chamber includes a radiant zone, a convection zone and an exhaust stack 1. For appropriate handling of emissions generated from the burning of liquid fuels, a scrubber 46 can be operationally mounted in exhaust stack 1. The outer wall is lined with a refractory lining capable of withstanding gas or liquid fuel firing.

While heater has been shown in an upright configuration, other configurations, such as a horizontal configuration, are useful.

The fired heater serves two main purposes. First, it heats the bitumen to the temperature required for firing. The particular bitumen characteristics suitable for firing depend on factors such as the quality of the bitumen, type of burner, etc. For example, a bitumen sample, when useful for firing can be generally at about 200°C (392°F) and atomized with steam at generally 0.1 to 0.075 pounds of steam per 1 pound of bitumen.

The fired heater also heats the water/steam to a temperature which offsets the shortfall in heat liberation from a liquid fuel flame of the same or similar size to a gaseous fuel flame to suit the dimensions and configuration of the boiler. Thus, heat available from liquid fuel firing in the steam injection boiler can be adequate to meet both steam throughput and steam quality, for example to 80% quality, requirements upon outlet from the steam injection boiler. As such, fired heater H1 has disposed through its combustion chamber water/steam coils 7 and 9 and a fuel heating coil 8. Water, which may depending on the source thereof be treated, heated and/or be converted partially to steam, is passed from a supply line 29 through inlet 32 to coil 7. Coil 7 is disposed in the convection zone of the heater and is connected to coil 9, which is disposed in the higher temperature radiant zone. Coils 7 and 9 are selected to handle passage therethrough of hot pressurized water and to accommodate the conditions within the combustion chamber, with respect to temperature and gases. Suitable materials are, for example, carbon steel, an alloyed metal for example chromium steel of, for example, 1 ¼ Chrome and ½ Molybdenum (P11) or stainless steel.

Fuel heating coil 8 is disposed in combustion chamber with consideration as to the temperature conditions and its effect on the fuel, for example, with respect to coking. In one embodiment, the fuel heating coil is mounted in the convection zone between the refractory lining and the water/steam coil 7 such that it is shielded, by coil 7, from direct radiation effects of the combustion process, to avoid coking within the coil. Suitable materials are, for example, alloyed metals, such as P11, or stainless steel.

Conversion unit 44, in addition to heater H1, includes the lines and connections for connecting the heater to a source of fuel and to a steam injection boiler. In particular, a line 48 is connected to coil 8 to supply fuel to be heated to the heater. Coil 8 can include a bitumen storage tank 25, if desired, and can include heating means, if such means are needed to keep the bitumen is a flowable state. Pumps, dewatering devices and other means can be installed in line 48 to provide for liquid fuel handling and preparation for use as a fuel.

A line 50 communicates with an outlet from coil 8 and is connectable at end 52, directly or indirectly, to the burner of a steam injection boiler that is to be fitted with the conversion unit. Conversion unit 44 can also include a liquid fuel compatible burner 16a for replacement of the gaseous fuel burner of the steam injection boiler.

Line 50 passes the heated fuel to the steam injection boiler and includes various means for facilitating such passage such as, for example, pumps 14, expansion tank 26 and fuel system 10 including, for example, valving, meters for temperature and pressure, heat tracing, etc. In the illustrated embodiment, where fuel is not only intended to be used in the steam injection boiler but also to be used in the heater itself, line 50 includes a connection to line 12.

Conversion unit 44 also includes a line 4 that communicates with an outlet from coil 9 and is connectable at its end 54 to, directly or indirectly, the water steam coils of the steam injection boiler which is to be fit with the conversion unit. Line 4 permits passage of preheated water to the steam injection boiler. It is to be understood that conversion unit 44 in the illustrated embodiment is set up to preheat water and delivers it to the inlet of a steam injection boiler. However, the heater could be set up to accept and heat water/steam that has already passed through the boiler, before it is passed to production.

If desired, the conversion unit can include various other components to enhance operation of the converted boiler or to meet environmental, safety, etc. requirements. For example, with reference to Figure 3, the conversion unit can include a scrubber 23 and soot blowers 34 for the steam injection boiler or a duct 2 for diverting the heater exhaust to the steam injection boiler combustion chamber. As another example, fuel line 50 can be fit with a fire valve (not shown).

To install the conversion unit, the heater can be set up without affecting operation of the steam injection boiler. Line 48 is connected to a source of liquid fuel and lines 50 and 4 are run to a position adjacent the steam injection boiler. For the final tie in, the gas burner will be replaced by the appropriate burner 16a and lines 50 and 4 will be connected while all other work associated with the fired heater may be completed without any interference to the operating boiler. The lines can be connected to the steam boiler in any way, as by fixed connection such as welding or by releasable connection such as by quick-release fittings, flanges, etc.

If desired, installation of the conversion unit can include various other procedures to enhance operation of the converted boiler or to meet environmental, safety, etc. requirements. For example, since most conventional boilers have a water pre-heater (economizer) coil (item 21 in Figure 1) below the exhaust stack and since most of these coils have finned surfaces, these coils can either be de-finned or replaced with studded tubes to accommodate liquid fuel firing. As another example, in respect of gaseous fuel fired boilers which are lined with ceramic fiber, the ceramic fiber could be covered with stainless steel liners to accommodate liquid oil firing (i.e. in case of oil leakage or spillage, to avoid any soaking of oil into the ceramic fiber). In addition, or alternately, boiler components may have to be treated to address corrosion issues, such as those relating to the deposit of vanadium pentoxide, discussed hereinbelow.

Use of the conversion unit to permit liquid fuel firing in a steam injection boiler is best understood by reference to a steam generation apparatus including a fired heater and a steam injection boiler. Thus, reference is made to Figure 3, which shows schematically such an apparatus.

Figure 3 schematically illustrates a steam generation apparatus including a steam injection boiler B1 that has been converted, by installation of a conversion unit 44, to be capable of liquid fuel, such as heavy oil and, particularly in this embodiment, bitumen, firing.

Conversion unit 44 is substantially as described in Figure 2. Line 29 extends to provide passage of water from boiler preheat coil 21 to inlet 32 of fired heater H1. Line 4 is connected to inlet 35 of boiler steam coil 5. Boiler burner 16a is operable to handle a liquid fuel source. Line 50 is connected to burner 16a. Atomizing steam lines 3, 3a and 3b are connected between the boiler

steam output lines and the burners 16a and 24. It may be necessary to incorporate a steam water separator 36 to isolate the steam from the steam water mixture for use as atomizing steam.

Rather than mounting a scrubber in exhaust stack 1, a duct 2 extends between heater exhaust stack 1 and the boiler combustion chamber and exhaust stack 1 has mounted therein a damper 27 to control whether combustion gases continue to outlet through exhaust stack or are diverted through duct 2. Flue gas circulation through the duct is driven by fan 13. Expansion joints, such as joint 15, can be provided in the duct

Boiler B1 is modified slightly to handle liquid fuel combustion. In particular, as noted, burner 16a is selected to be liquid fuel compatible and includes a steam injection line 3b for fuel atomization. Boiler B1 accepts outlet of duct 2, which most conveniently for exhaust product handling, opens adjacent the burner end of the combustion chamber. Soot blowers 34 are mounted to address the accumulation of solids. Exhaust stack 28 has mounted thereon a scrubber 23 for handling flue gases generated from burning bitumen. To reserve scrubber operation for only times when it is needed, scrubber 23 is mounted in a bypass duct 56 on exhaust stack and a plurality of dampers 22 and 30 are mounted to control direction of flue gas flow.

In use, start up procedures will vary depending on the embodiments of the heater and boiler and on the site conditions. For example, the start-up procedure will vary depending on whether the steam generation apparatus is being used on an already producing or on a new well. In particular, since bitumen is most desirably used as it is produced, the heater/boiler may have to be fired with an alternate fuel source to begin steam generation for driving bitumen production.

Startup of auxiliary heater H1 is achieved by initially firing gas or liquid petroleum gas. Once the operating condition for the fired heater H1 is stabilized, bitumen flow through coil 8 is initiated and a suitable bitumen temperature (i.e. as the fuel source, for example, for firing the fired heater H1 and the boiler B1) is achieved, burners 24 and 16a are fired up using bitumen as fuel. The bitumen can be from any source. However, since the steam generation apparatus is usually on site of a production facility, the bitumen is advantageously from production. It is useful to use the bitumen substantially directly as it is produced, such that it retains latent heat of

production and thereby has reduced viscosity over bitumen which has been allowed to cool or requires reheating just to be pumpable.

Treated water enters the apparatus through line 19 and is pumped to the required pressure by the boiler feed pump 33. The high pressure water enters the steam injection boiler B1 convection zone primary preheater coils 21. The preheated water then crosses over to the auxiliary heater H1 convection zone via line 29 and enters the fired heater H1 at the hot water inlet 32 where it enters the secondary water preheat coil 7. The heated water from the preheat coil 7 is fed to the radiant zone steam water coil 9 where it is heated to meet desired inlet conditions at the boiler (B1 inlet at 5). The steam water then passes through boiler coil 5 and a steam water mixture at the desired conditions (i.e. 80% quality steam or other desired quality steam) emerges from the boiler B1 at outlet 20 for injection into the oil seams, as necessary.

A slip stream of steam can be diverted via lines 3, 3a and 3b to the burners 16a, 24 for atomization of bitumen.

Bitumen enters the system at the bitumen storage tank 25 and is pumped by pump 14 into the auxiliary fired heater H1 convection box. Once heated by passage through coil 8, the heated bitumen returns to the bitumen expansion tank 26 and, in turn is pumped into the fuel handling system 10. The correctly heated bitumen is then fed via heated lines 11 and 12 to the burners 24 and 16a for the heater H1 and the boiler B1, respectively. The bitumen feed to both of these burners 24 and 16a is atomized into the fireboxes using steam from lines 3a, 3b.

At startup, combustion by-products from auxiliary fired heater H1, which are generated from combustion of gaseous fuel such as petroleum, natural gas or liquid petroleum, can be vented to the atmosphere via the auxiliary heater stack 1. Once both units B1 and H1 are operational and burning bitumen, the flue gases from the fired heater H1 are redirected to the boiler B1 by closing the damper 27 and starting up the recirculation fan 13 located on the flue gas recirculation duct 2.

The combustion by-products from the burning of gaseous fuel in heater H1 can be vented to the atmosphere via exhaust stack 1. For example, during startup it may be desirable to use gaseous

fuel in the heater damper 27 is open. When the bitumen has been heated to the required firing temperature, bitumen combustion can be commenced in heater H1. During this start-up procedure, all exhaust products can be vented to atmosphere via stack 1, with the damper open and fan 13 out of service. Once steady state conditions are established in heater H1 and all pre-start conditions are satisfied with boiler B1, burner 16a is fired up. Dampers 30 will be closed and damper 22 will be open and exhaust products will be vented to atmosphere via stack 28. Upon achieving a steady state condition, in boiler B1, fan 13 will be brought into service while damper 27 is slowly closed and all combustion products are introduced to boiler B1 via duct 2. Once steady state conditions are achieved in both the heater and the boiler, then dampers 30 will be opened and damper 22 will be closed. Heater H1 firing can now be modulated to achieve a desired quality of steam at outlet 33.

Once the steam generation apparatus has been successfully started up, all emission reduction treatment means can be activated. Sulfer dioxide (SO_2) will be treated at the by-pass scrubber 23 using technologies such as Sulfire™, lime or amine systems. Metals, ash, and other components can be collected, stabilized and disposed of at suitable landfill sites in accordance with applicable legislation, guidelines, accepted practice or as otherwise permitted by applicable authorities. By connecting the fired heater exhaust in series with the original steam generator, the combustion products are directed into the original steam generator for effective NOx reduction/mitigation and only one scrubber is required.

The conversion unit permits the boiler to be fired with bitumen (or other liquid fuel) and to generate necessary qualities and quantities of steam, while the bitumen flame in the boiler combustion chamber adheres to required clearances between the flame and the tube surfaces and refractory lining. This is done by shaping the bitumen flame to suit the enclosure, with an appropriate assessment made to determine the firing rate that can be safely accommodated. Any shortfall in steam generation arising from the lower firing rate of bitumen is recovered/generated in the fired heater. If necessary, the design can readily permit conversion back to gas firing by use of dual fuel burners in the heater and in smaller boilers or replacement of the liquid fuel burner. Where higher steam production rates are desired, gas firing could be used in both the fired heater and the boiler. This could be achieved by using bitumen heating coils 8 with suitable

metallurgy, for example, a 316 stainless steel or equivalent, that would allow heater operation while coil 8 is dry.

The combustion in the fired heater can be controlled to control steam quality and throughput. This control can be achieved by adjustment of the firing rate of the fired heater such as, for example, by adjustments of the firing rate at burner 24. For example, the firing rate of the fired heater can be adjusted to select for steam quality at inlet 35 and therefore steam quality at outlet 20. Larger BTU input in the heater results in greater quality and/or quantity steam production. For example, a higher quality steam, of greater than 80%, can be produced, with consideration to water coil fouling due to water deposits. It is easier to control heater firing rate than boiler firing rate, since the heater's combustion chamber can be formed to accommodate various size flames. Generally, it is desirable to operate the boiler at a maximum firing rate and to control the heater firing rate to achieve finer control over steam quality and quantity. Also, the additional water heating capability of the heater is such that the steam production losses due to use for bitumen atomization can be made up by producing extra steam. Since the production of bitumen from in situ production varies proportionally with the rate of steam injection, extra steam production can be supplied for downhole injection to drive increased bitumen production. For example, the heating capability of the heater is such that the production losses due to bitumen use for steam generation firing can be made up by extra production of steam resulting in increased bitumen production, such that after the boiler/heater fuel requirements are met, the desirable production rates from the site are maintained.

It is also possible to use one heater to serve two or more boilers. Depending on the size of the boilers, for example, it is possible to serve two steam generating boilers, of, for example, 80,000 kg/hour capacity, with one fired heater.

The burning of bitumen may require modifications in the boiler to address corrosion issues of internal parts. Bitumen contains various metals, such as vanadium and chromium. As bitumen combusts, vanadium deposits will occur along convection tube surfaces in the form of vanadium pentoxide V_2O_5, which apart from being highly corrosive to chrome molybdenum tube supports, is equally effective in the conversion of sulfur dioxide SO_2 to sulfur trioxide SO_3, an even less desirable emission by-product of combustion. Tube supports may be stabilized by applying

suitable metal sprays, while successful treatment of SO_2 prior to its contact with vanadium pentoxide will help reduce the formation of SO_3. Use of bare tubes and suitable soot blowers located in the boiler and heater convection sections will greatly improve the life expectancy of these convection coils. Ash containing metals inherent to bitumen, such as chromium, et al, could be stabilized and disposed of in such manner(s) permitted by law. The convection tube surfaces in both the heater and the boiler could be washed periodically to remove any deposits.

It is to be understood that the invention is also applicable to the construction of new steam generation facilities. In particular, due to the logistical and economic problems of producing boilers designed specifically for burning liquid fuels, it may be desirable to use a boiler sized for gaseous fuel burning installed with a fired heater, for example in substantially the configuration of Figure 3. When manufacturing a new steam injection boiler intended for liquid fuel burning, consideration can at the outset be given to facilitating use of this fuel. For example, any new boilers can include a castable refractory lining, which is considered standard for liquid fuel firing, rather than fibrous refractories. As another example, the boiler can be entirely designed to operate with bitumen, rather than using a dual fuel burner. This presents significant cost advantages through the elimination of the need to install gas pipelines to transport gas to the operating area of the steam generation apparatus. In this regard, initial firing of the heater during initial startup may be with propane or another on-site fuel source.

As an example, referring to Figure 4, another steam generation apparatus is shown, which has been built for the purpose of burning liquid fuel. The boiler B2 and heater H2 are more integrated than in Figure 3. In particular, the apparatus has two radiant zone coils: a boiler coil 5a and a heater coil 9a, but only one convection zone coil 60 in a convection area 62 merged between the two units B2, H2. Water is introduced at inlet 64 passes through coils 60 and then passes through tube 66 to coils 9a where it is preheated to a final selected temperature for passage, via tube 68, to coils 5a of the boiler wherein steam is generated and outlet at 20a.

Convection area 62 also includes a fuel tube 8a, which heats fuel to be provided through tubes 69 to both the heater burner 24 and the boiler burner 16a.

The apparatus includes one exhaust stack 70 including a scrubber 74 mounted therein.

In another embodiment, the steam apparatus can be formed such that the radiant zone of the heater is sufficient to preheat the water without requiring passage through a convection zone. However, such an embodiment may be considered wasteful as considerable heat will be lost without recovery from the combustion gases.

Referring to Figure 5, another steam generation apparatus is shown that can be used to consistently produce high quality steam of, for example, greater than 80% consistently without concern as to steam generation shut down for defouling of water tubes which is the greatest deterrent to generation of greater than 80% steam and without the need to invest in pre-boiler water treatment. The apparatus includes a pair of step-up heaters H3a and H3b in association with a boiler B1. The heaters H3a and H3b are positioned to further heat the steam from line 80 as it passes out of the boiler, such steam being for example at a maximum of about 80%, to increase the volume of steam per volume. The heaters are positioned in parallel, each having a supply line 82a, 82b, steam generation coils 84a, 84b and outlet lines 86a, 86b. A valve 88 controls steam flow from line 80 into one of the heaters H3a, H3b. Coils 84a, 84b are deliberately selected and configured to foul up from water deposits, but valve controls steam flow so that only one heater is in operation at one time. Thus, when necessary, one of the heaters, for example H3a, can be chemically cleaned while the other heater, H3b, remains in operation to generate high quality steam. Once the coils of heater H3a have been cleaned and the coils of heater H3b have fouled to the extent that they require cleaning, heater H3a can be fired up and valve 88 can be actuated to take heater H3b off line, by directing flow to line 82a, coils 84a, and line 86a. This permits heater H3b to be cleaned while the generation of high quality steam is not interrupted. These parallel step up heaters can be repositioned to preheat water prior to flow into the boiler, if desired.

It is to be noted that the parallel step up heaters can be used with a gaseous fuel or a liquid fuel fired boiler. In addition, the heaters H3a, H3b can be gaseous fuel fired or liquid fuel fired. Of course, if the heaters are used with a liquid fuel fired boiler, it is useful to also have the heaters fired by liquid fuel. For example, with reference to Figure 6, boiler B1 and heaters H3a, H3b are fired by liquid fuel through lines 90. Flue discharge from heaters H3a, H3b are routed via ducts 92 to the boiler flue exhaust or to the fired preheater H1 flue exhaust.

Although preferred embodiments of the present invention have been described in some detail hereinabove, those skilled in the art will recognise that various substitutions and modifications may be made to the invention without departing from the scope and spirit of the appended claims.

Claims:

1. A steam generation apparatus comprising:

a steam injection boiler including a burner operable therein;

a fired heater including a heater burner;

a water tube circuit extending through the fired heater and the steam injection boiler, the tube selected to convey water in order to heat the water to generate steam;

a fuel tube extending through fired heater selected to convey liquid fuel in order to generate heated liquid fuel; and

a tube for conveying the heated liquid fuel to support the firing of the steam injection boiler.

2. The steam generation apparatus of claim 1 wherein the water tube circuit passes first through the fired heater and then through the steam injection boiler.

3. The steam generation apparatus of claim 1, the heater further including a convection zone and a radiant zone and wherein the water tube circuit passes through the fired heater convection zone and the fired heater radiant zone.

4. The steam generation apparatus of claim 1, the steam injection boiler further including a convection zone and a radiant zone and wherein the water tube circuit passes, in series, through the boiler convection zone, the fired heater and the boiler radiant zone.

5. The steam generation apparatus of claim 1 wherein the heater burner operates on gaseous fuel.

6. The steam generation apparatus of claim 1 wherein the heater burner is capable of operating on both gaseous fuel and liquid fuel.

7. The steam generation apparatus of claim 6 further comprising a tube for conveying the heated liquid fuel to support the firing of the fired heater.

8. The steam generation apparatus of claim 1 the fired heater further including a convection zone and wherein the fuel tube passes through the fired heater convection zone in order to generate heated liquid fuel.

9. The steam generation apparatus of claim 8, wherein the water tube circuit passes through the fired heater convection zone and the fuel tube is shielded by the water tube circuit to reduce coking in fuel tube.

10. The steam generation apparatus of claim 1, the steam injection boiler further including an exhaust stack and a scrubber operationally mounted in the exhaust stack.

11. The steam generation apparatus of claim 1 wherein the heater burner is capable of operating on liquid fuel and the fired heater being in communication with an exhaust stack including a scrubber operationally mounted therein.

12. The steam generation apparatus of claim 1 further comprising ducting between the fired heater and the steam injection boiler, an exhaust stack and a scrubber operationally mounted in the exhaust stack and wherein the flue gases generated by both the heater and the steam injection boiler are passed through the exhaust stack.

13. The steam generation apparatus of claim 1 wherein the firing rate of the heater burner can be adjusted to adjust steam quality and/or quantity generated by the steam generation apparatus.

14. A steam injection boiler conversion unit for converting a steam injection boiler from gaseous fuel firing to be capable of liquid fuel firing, the steam injection boiler including a burner operable therein and a boiler tube extending therethrough, the steam injection boiler conversion unit comprising:

a fired heater including a heater burner;

a water tube extending through the heater, the water tube selected to convey water in order to heat the water and the water tube being connectable into fluid flow communication with the boiler tube such that, when connected, fluid passing from the water tube can pass into the boiler tube;

a fuel tube extending through the heater, the fuel tube selected to convey liquid fuel in order to generate heated liquid fuel; and,

a line connectable into fluid flow communication with the burner of the boiler for supplying the heated liquid fuel to support the firing of the boiler burner, when the conduit is connected to the boiler burner.

15. The steam injection boiler conversion unit of claim 14, wherein the fired heater is operable to heat the liquid fuel to a temperature suitable for firing the boiler burner.

16. The steam injection boiler conversion unit of claim 14, wherein the fired heater is operable to preheat the water and delivers it to the inlet of the steam injection boiler at a temperature that offsets the shortfall in heat liberation from a liquid fuel flame suitable for generation within the steam injection boiler.

17. The steam injection boiler conversion unit of claim 14, the heater further including a convection zone and a radiant zone and wherein the water tube passes through the fired heater convection zone and the fired heater radiant zone.

18. The steam injection boiler conversion unit of claim 14, the steam injection boiler further including a convection zone and a radiant zone and wherein the water tube receives water having already passed through the boiler convection zone.

19. The steam injection boiler conversion unit of claim 14 wherein the heater burner operates on gaseous fuel.

20. The steam injection boiler conversion unit of claim 14 wherein the heater burner is capable of operating on both gaseous fuel and liquid fuel.

21. The steam injection boiler conversion unit of claim 20 further comprising a tube for conveying the heated liquid fuel to support the firing of the fired heater.

22. The steam injection boiler conversion unit of claim 14 the fired heater further including a convection zone and wherein the fuel tube passes through the fired heater convection zone in order to generate heated liquid fuel.

23. The steam injection boiler conversion unit of claim 22, wherein the water tube circuit passes through the fired heater convection zone and the fuel tube is shielded by the water tube to reduce coking in the fuel tube.

24. The steam injection boiler conversion unit of claim 14 wherein the heater burner is capable of operating on liquid fuel and the fired heater being in communication with an exhaust stack including a scrubber operationally mounted therein.

25. The steam injection boiler conversion unit of claim 24 further including a duct connectable to the boiler for passing flue gases to the steam injection boiler.

26. A method for converting a steam injection boiler from gaseous fuel firing to be capable of liquid fuel firing, the steam injection boiler including a burner operable therein and a boiler tube extending therethrough, the method for converting comprising:

providing a fired heater including a heater burner, a water tube extending through the heater, the water tube selected to convey water in order to heat the water and a fuel tube extending through the heater, the fuel tube selected to convey liquid fuel in order to generate heated liquid fuel;

bringing the water tube in fluid flow communication with the boiler tube such that fluid passing from the water tube can pass into the boiler tube; and

conveying the heated liquid fuel to the burner of the boiler to support the firing of the steam injection boiler.

27. The method of claim 26 further comprising replacing the burner of the steam injection boiler with a burner compatible with liquid fuel burning.

28. The method of claim 26, further comprising modifying the steam injection boiler to handle at least some of the emissions from liquid fuel combustion.

29. The method of claim 26, the steam injection boiler further including an exhaust stack and the method further comprising, installing in the exhaust stack a scrubber for handling at least some of the emissions from liquid fuel combustion.

30. The method of claim 26, wherein the steam injection boiler can continue to be operated until the step of bring the water tube into fluid communication with the boiler tube.

31. A method for generating steam for in situ production of petroleum products, the method comprising:

providing a steam generation apparatus including a steam injection boiler having a burner operable therein; a fired heater including a heater burner; a water tube circuit extending through the fired heater and the steam injection boiler, the water tube circuit selected to convey water in order to heat the water to generate steam; a fuel tube extending through the heater selected to convey liquid fuel in order to generate heated liquid fuel; and a line for conveying the heated liquid fuel to support the firing of the steam injection boiler;

firing the fired heater to heat a supply of liquid fuel passing through the fuel tube;

conveying the liquid fuel through the conduit to support firing of the steam injection boiler; and

passing a flow of water through the water tube circuit such that steam is generated.

32. The method for generating steam for in situ production of petroleum products of claim 31 wherein the liquid fuel is taken from in situ production.

33. The method for generating steam for in situ production of petroleum products of claim 32 wherein the liquid fuel is used while it retains latent heat from production.

34. The method for generating steam for in situ production of petroleum products of claim 31 further comprising operating the fired heater on gaseous fuel initially and, thereafter, operating the fired heater with heated liquid fuel.

35. The method for generating steam for in situ production of petroleum products of claim 31, the method further comprising adjusting steam quality generated by adjusting the firing rate of the fired heater.

36. A steam generation apparatus comprising:

a steam injection boiler including a burner operable therein and a boiler water coil extending through the steam injection boiler and including an outlet the boiler water coil selected to convey water in order to heat the water to generate steam;

at least a first heaters and a second heater, each including a steam heating circuit, the steam heating circuits being connected in parallel with each other and in fluid flow communication with the boiler water coil and the heater selected to increase the steam quality of the steam passing from the steam injection boiler; and

a flow controller to control flow through the first and the second heaters and actuable to select that flow is permitted through only a selected one of the first heater steam heating circuit and the second heater steam heating circuit.

36. A method for generating steam comprising:

providing a steam injection boiler including a burner operable therein and a boiler water coil extending through the steam injection boiler and including an outlet the boiler water coil selected to convey water in order to heat the water to generate steam; at least a first heaters and a second heater, each including a steam heating circuit, the steam heating circuits being connected in parallel with each other and in fluid flow communication with the boiler water coil and selected

to increase the steam quality of the steam passing from the steam injection boiler; and a flow controller to control flow through the first and the second heaters and actuable to select that flow is permitted through only a selected one of the first heater steam heating circuit and the second heater steam heating circuit;

conveying water through the boiler water coil and through the steam heating circuit of a selected one of the first heater or the second heater to generate steam from the water;

defouling the steam heating circuit of the other of the first heater or the second heater; and

switching flow to the other of the first heater or the second heater when the steam heating circuit of the selected heater when it is desired to defoul the selected steam heating circuit.

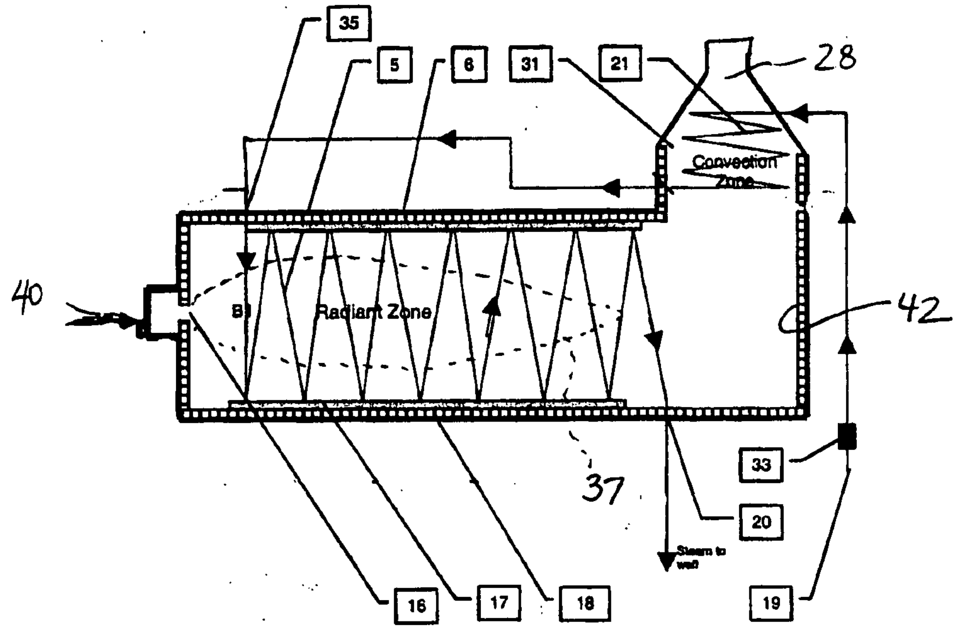

Figure 1 (prior art)

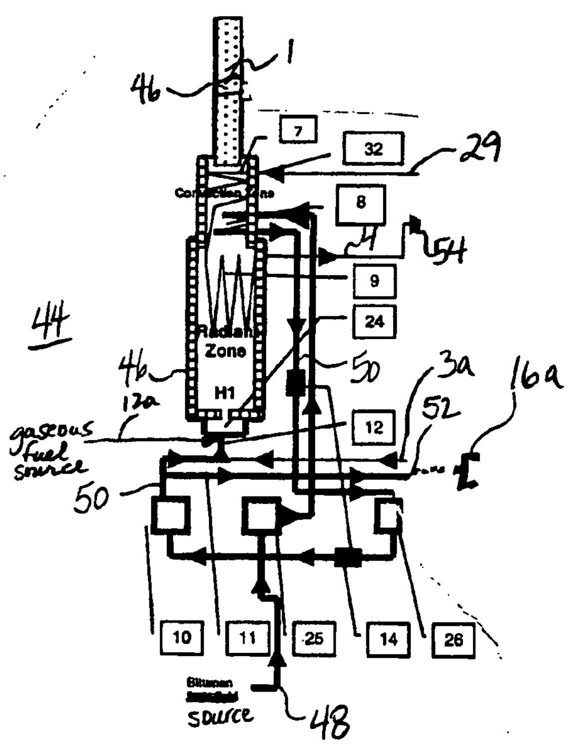

Figure 2

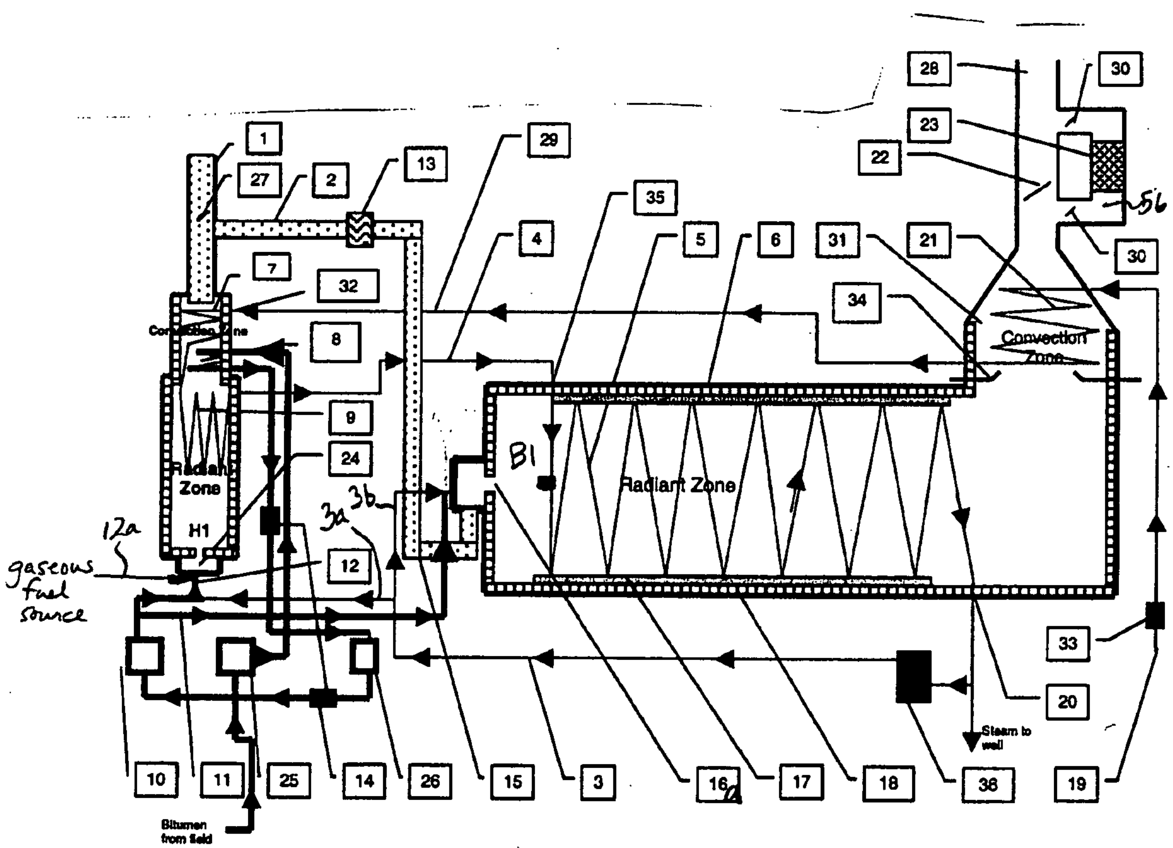
1
27
2
13
29
35
4
5
6
31
21
34
28
30
23
22
56
30
7
32
Convection Zone
8
9
24
Radiant Zone
H1
12a
gaseous fuel source
12
3a
3b
B1
Radiant Zone
Convection Zone
33
20
Steam to well
10
11
25
14
26
15
3
16a
17
18
36
19
Bitumen from field

Figure 3.

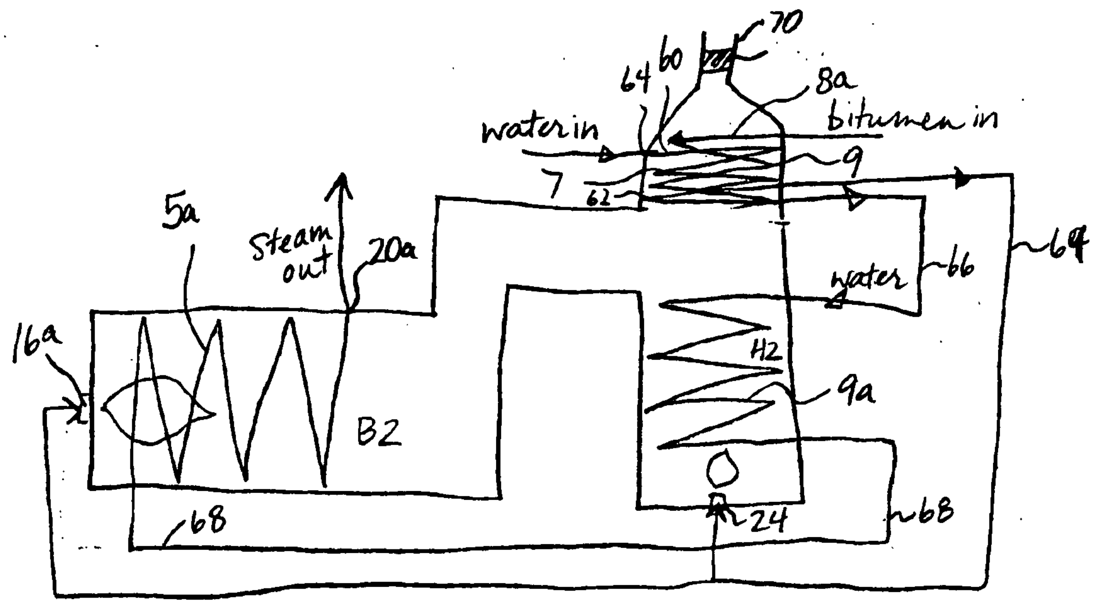
70
64
60
8a
water in
bitumen in
9
7
62
5a
Steam out
20a
water
66
64
16a
H2
9a
B2
68
24
68

Figure 4

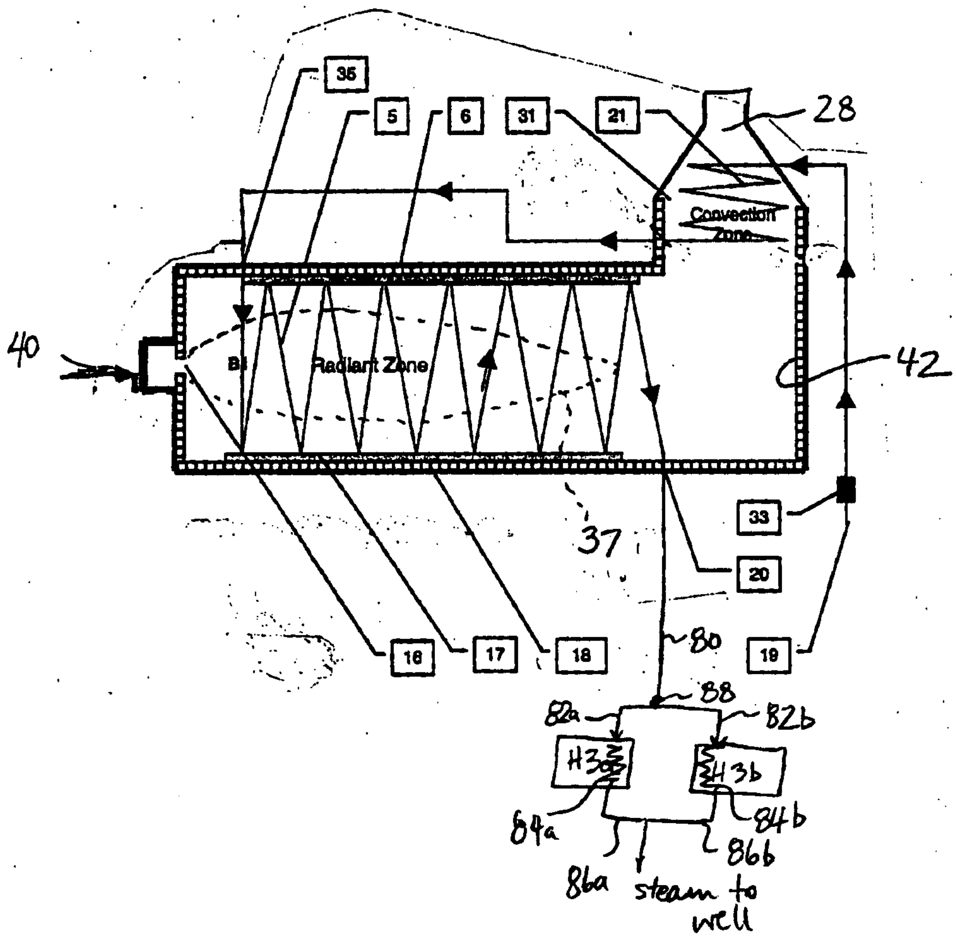
35
5
6
31
21
28
Convection Zone
40
Radiant Zone
42
33
37
20
16
17
18
80
19
88
82a
82b
H3a
H3b
84a
84b
86a
86b
steam to well

Figure 5.

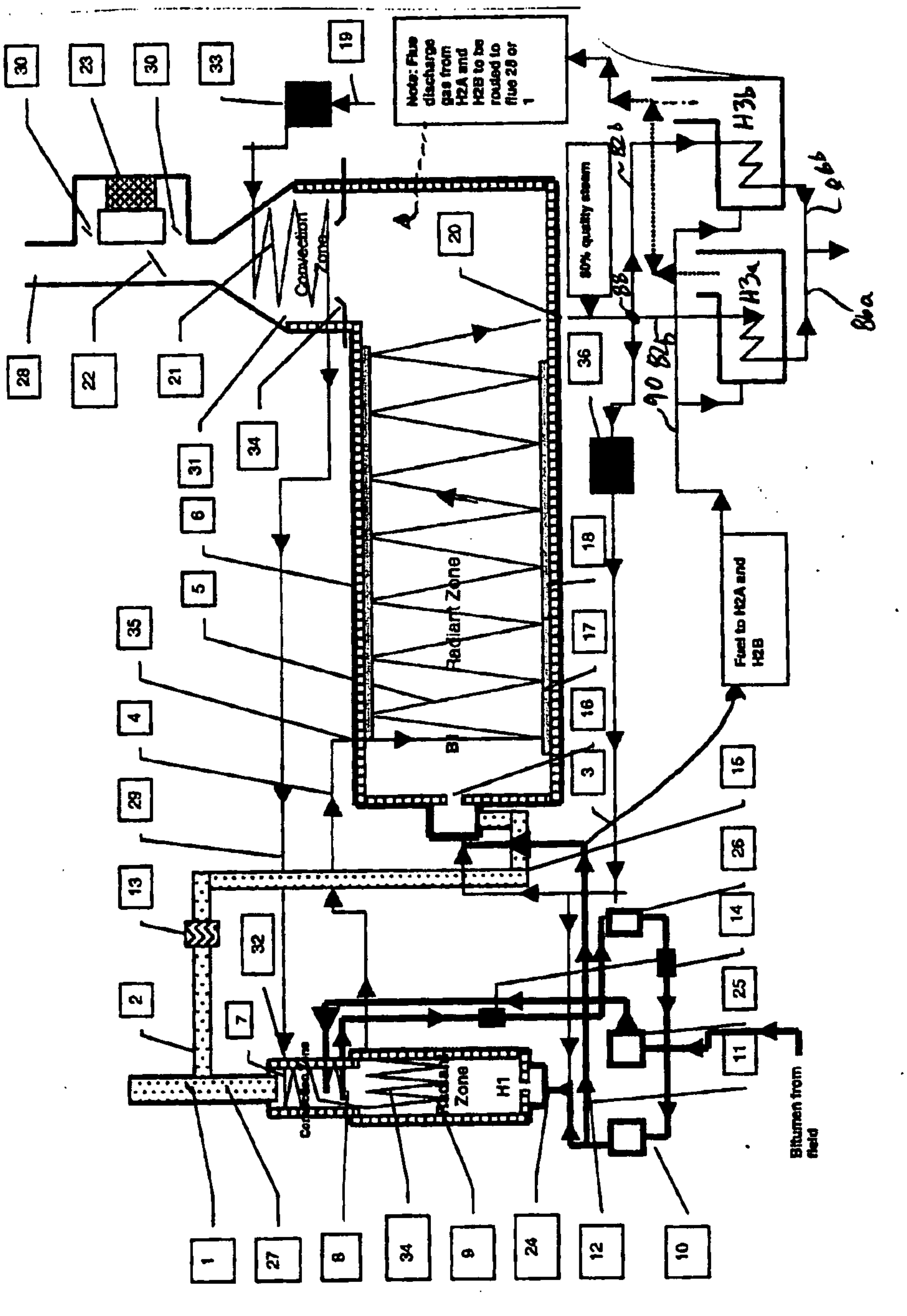
Note: Flue discharge gas from H2A and H2B to be routed to flue 28 or 1
80% quality steam
Fuel to H2A and H2B
Radiant Zone
Convection Zone
Bitumen from field
H1
H3a
H3b

Figure 6.